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(54) **ANTENNAS FOR ELECTRONIC DEVICES**

(75) Inventors: **Chris Ligtenberg**, San Carlos, CA (US); **Brett William Degner**, Menlo Park, CA (US); **Douglas Blake Kough**, San Jose, CA (US)

(73) Assignee: **Apple Inc.**, Cupertino, CA (US)

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(22) Filed: **Apr. 2, 2008**

(65) **Prior Publication Data**

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(51) **Int. Cl.**
H01Q 1/24 (2006.01)

(52) **U.S. Cl.** **343/702**; 455/557

(58) **Field of Classification Search** 343/702; 455/90, 557, 575

See application file for complete search history.

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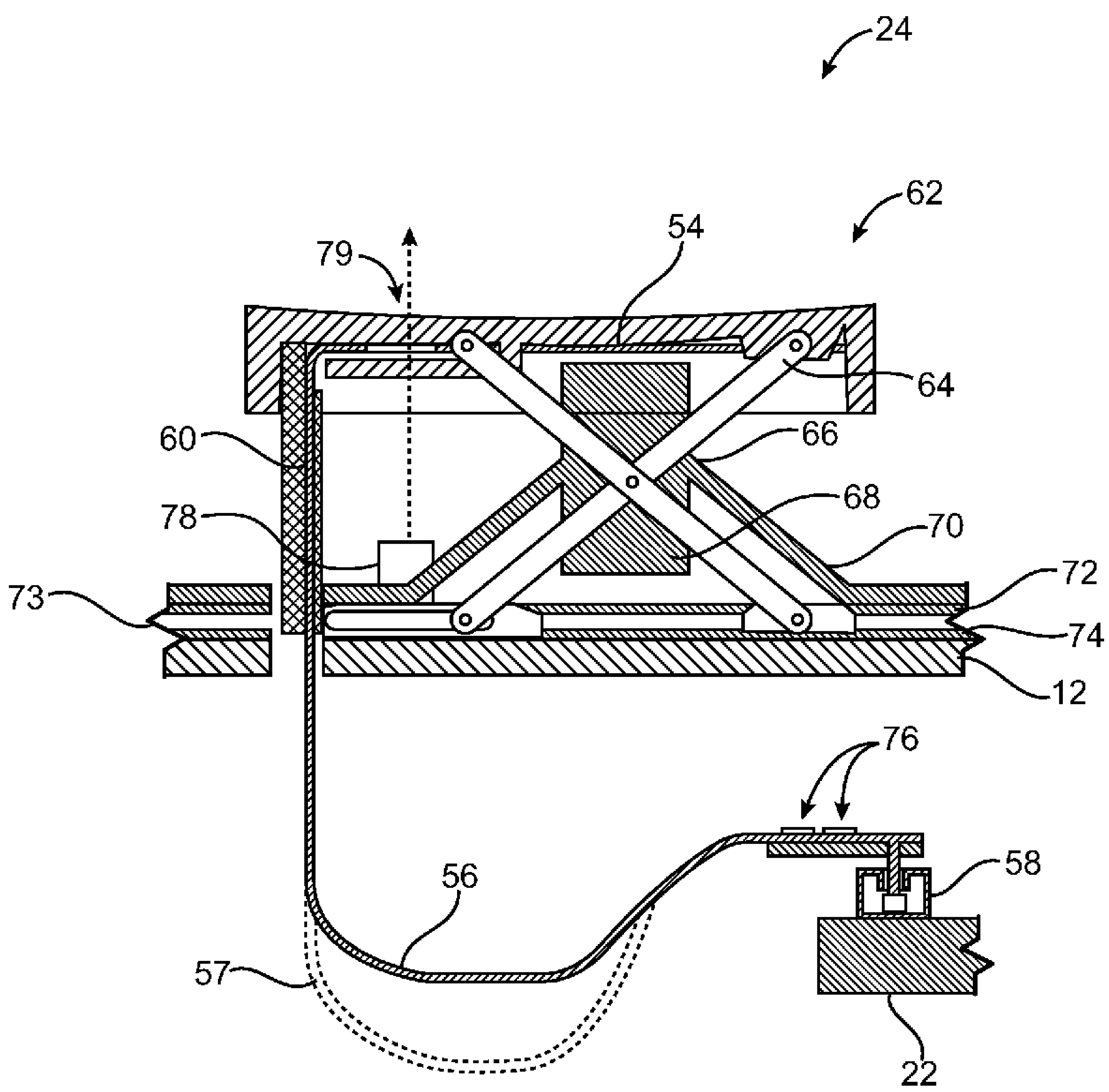
Primary Examiner — Tho G Phan

(74) *Attorney, Agent, or Firm* — Treyz Law Group; David C. Kellogg; G. Victor Treyz

(57) **ABSTRACT**

Key antennas are provided for an electronic device such as a laptop computer. The electronic device may have radio-frequency transceivers that transmit and receive signals using the key antennas. An antenna resonating element may be mounted beneath a keycap of each key antenna. The antenna resonating element may be spirally wrapped and integrated into the keycap. The key antenna may function as an antenna and may also function as an input key for an electronic device. A flexible communications path may pass through a hole in a conductive housing of the electronic device and may be used to couple the antenna resonating element to the radio-frequency transceiver. The antenna resonating element may be coupled to the radio-frequency transceiver by a weak spring. The weak spring may form a portion of the antenna resonating element.

23 Claims, 11 Drawing Sheets



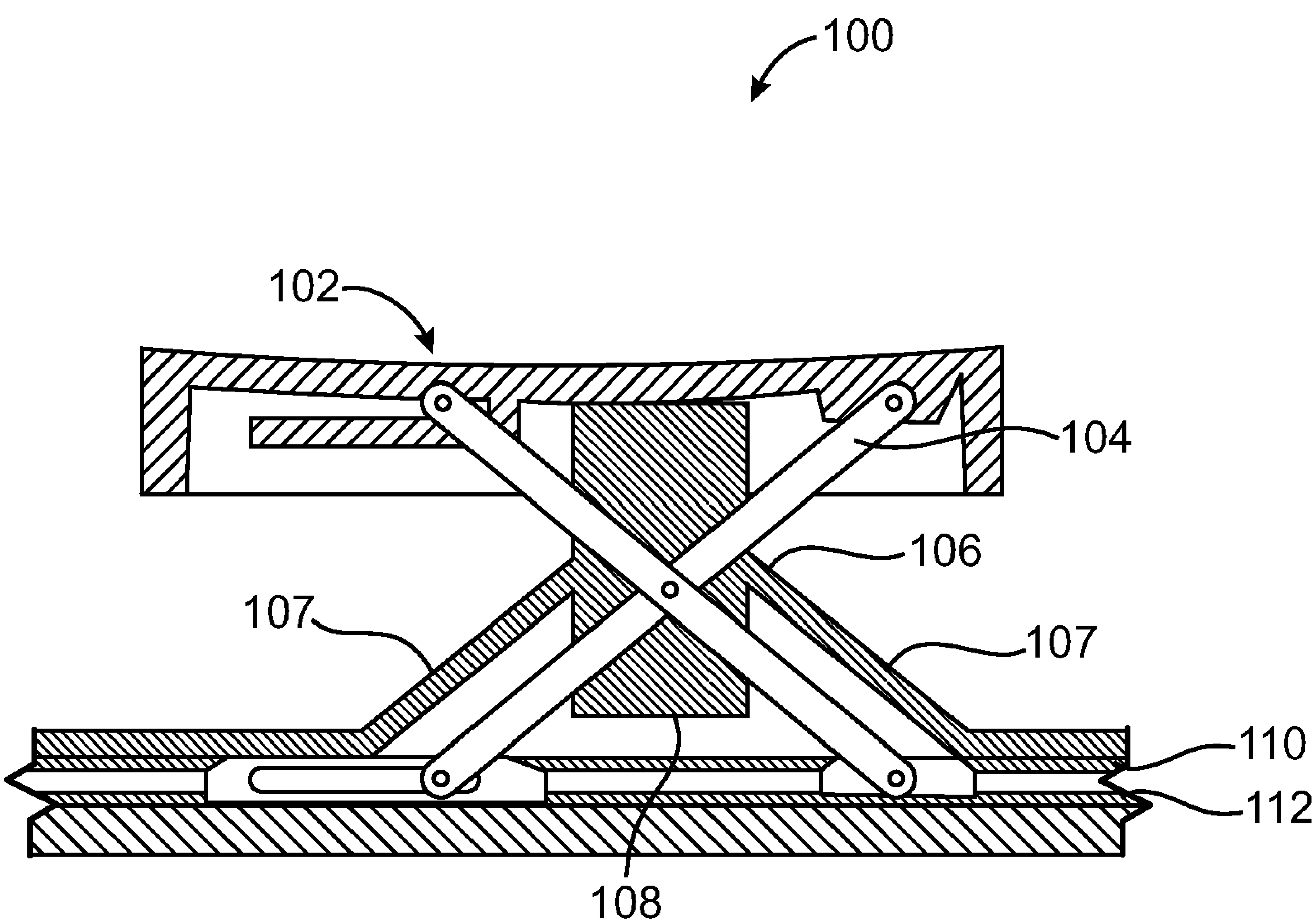


FIG. 1
(PRIOR ART)

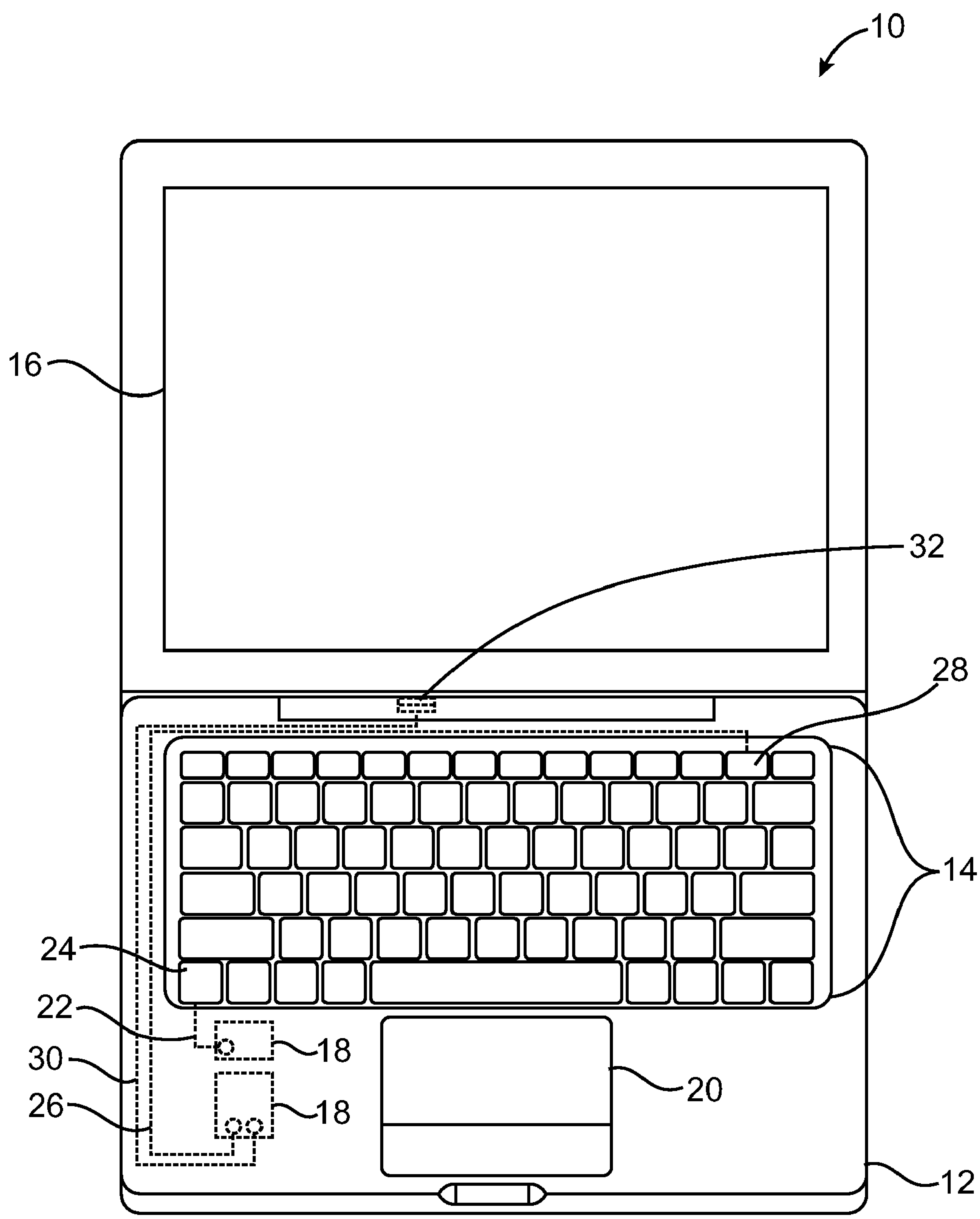


FIG. 2

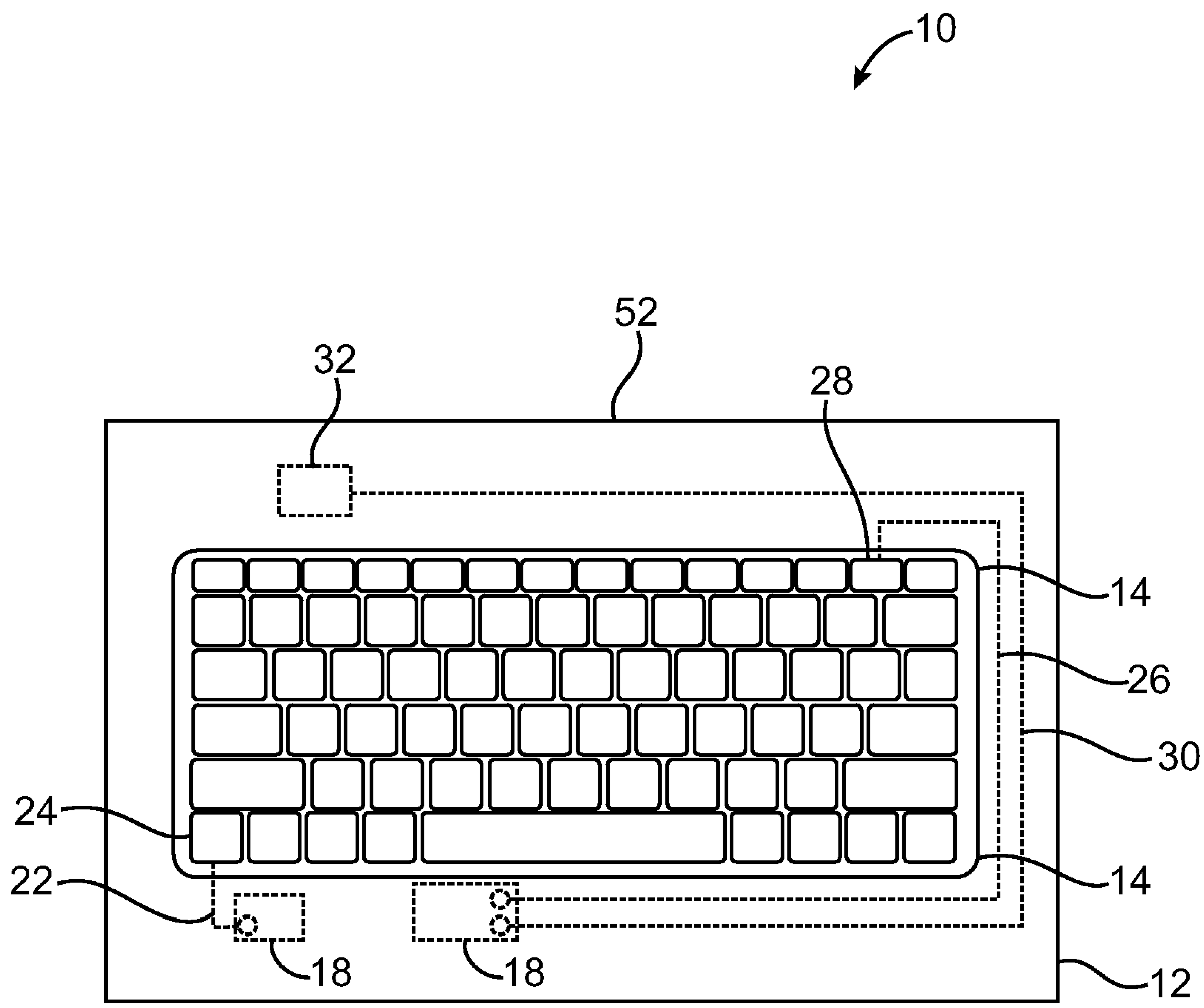


FIG. 3

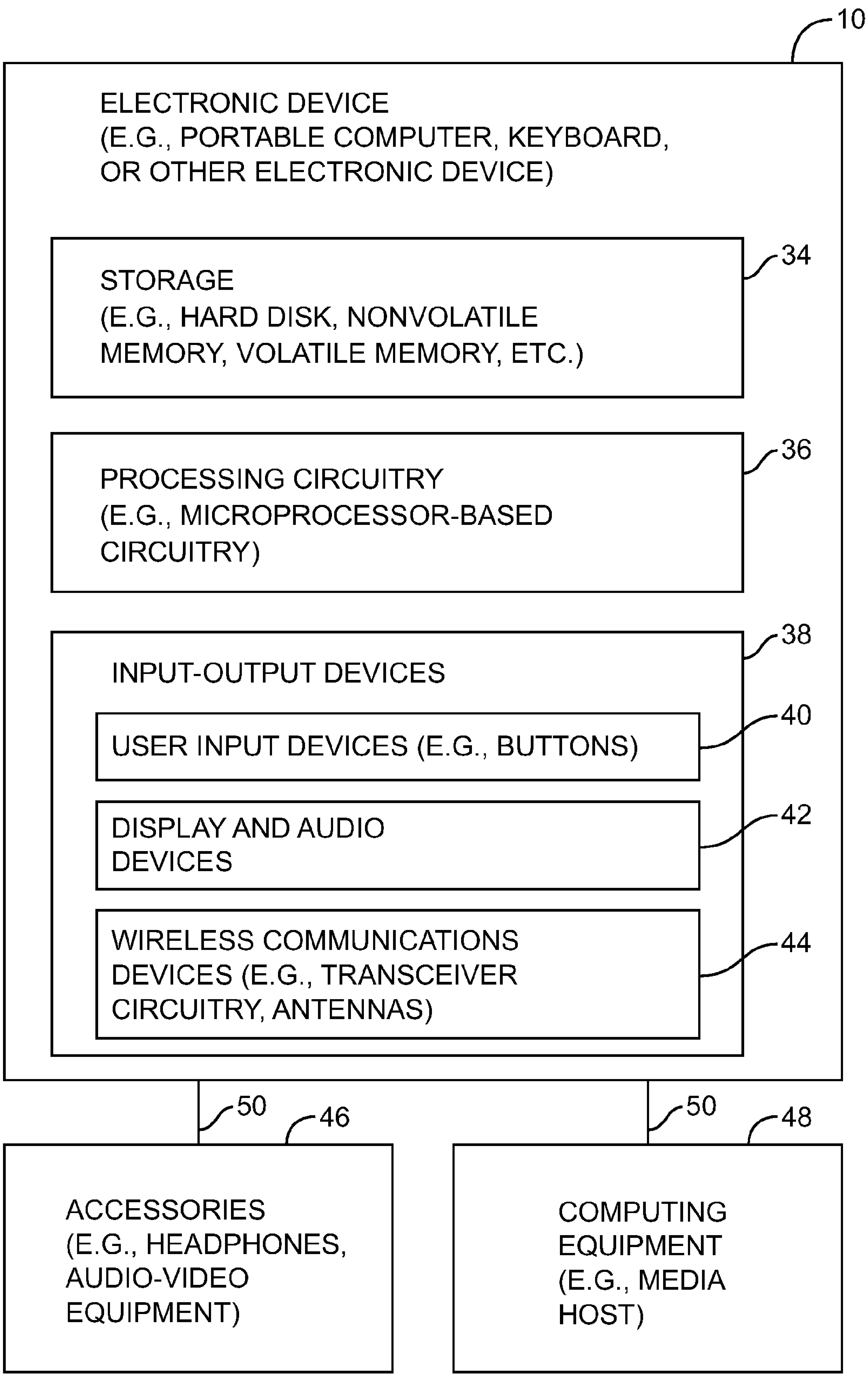

10
ELECTRONIC DEVICE
(E.G., PORTABLE COMPUTER, KEYBOARD,
OR OTHER ELECTRONIC DEVICE)
34
STORAGE
(E.G., HARD DISK, NONVOLATILE
MEMORY, VOLATILE MEMORY, ETC.)
36
PROCESSING CIRCUITRY
(E.G., MICROPROCESSOR-BASED
CIRCUITRY)
38
INPUT-OUTPUT DEVICES
40
USER INPUT DEVICES (E.G., BUTTONS)
42
DISPLAY AND AUDIO
DEVICES
44
WIRELESS COMMUNICATIONS
DEVICES (E.G., TRANSCEIVER
CIRCUITRY, ANTENNAS)
50
46
50
48
ACCESSORIES
(E.G., HEADPHONES,
AUDIO-VIDEO
EQUIPMENT)
COMPUTING
EQUIPMENT
(E.G., MEDIA
HOST)

FIG. 4

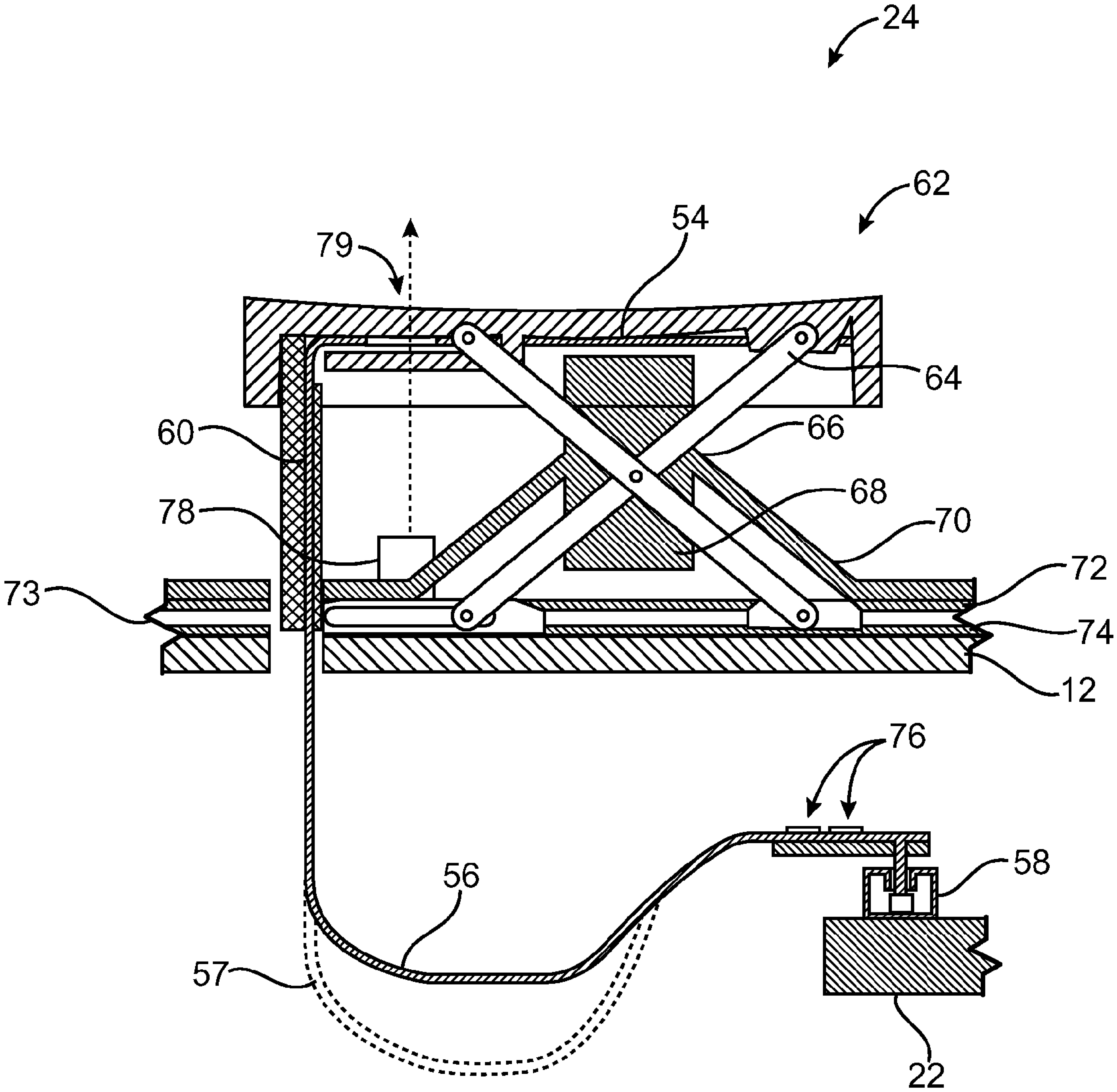


FIG. 5

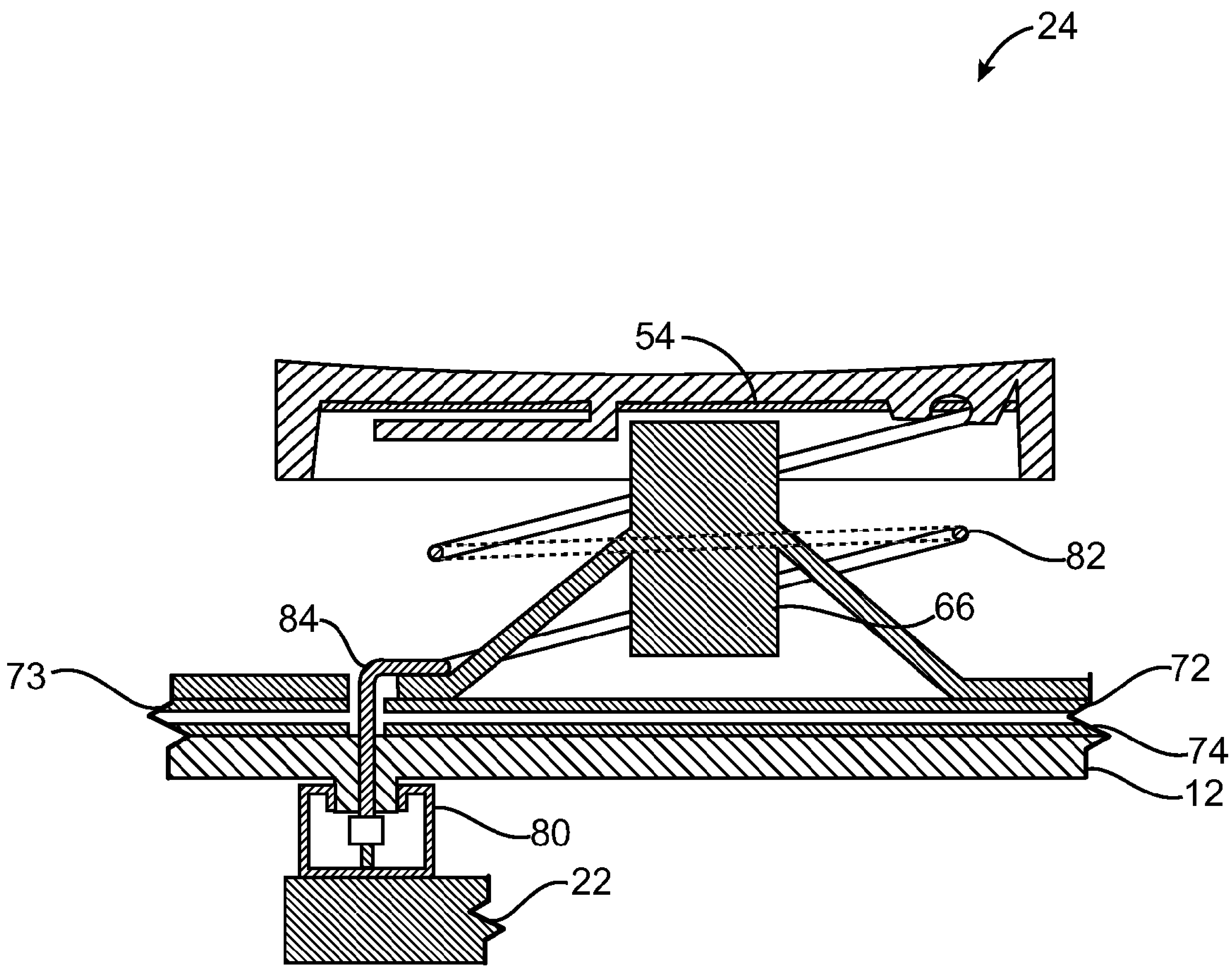


FIG. 6

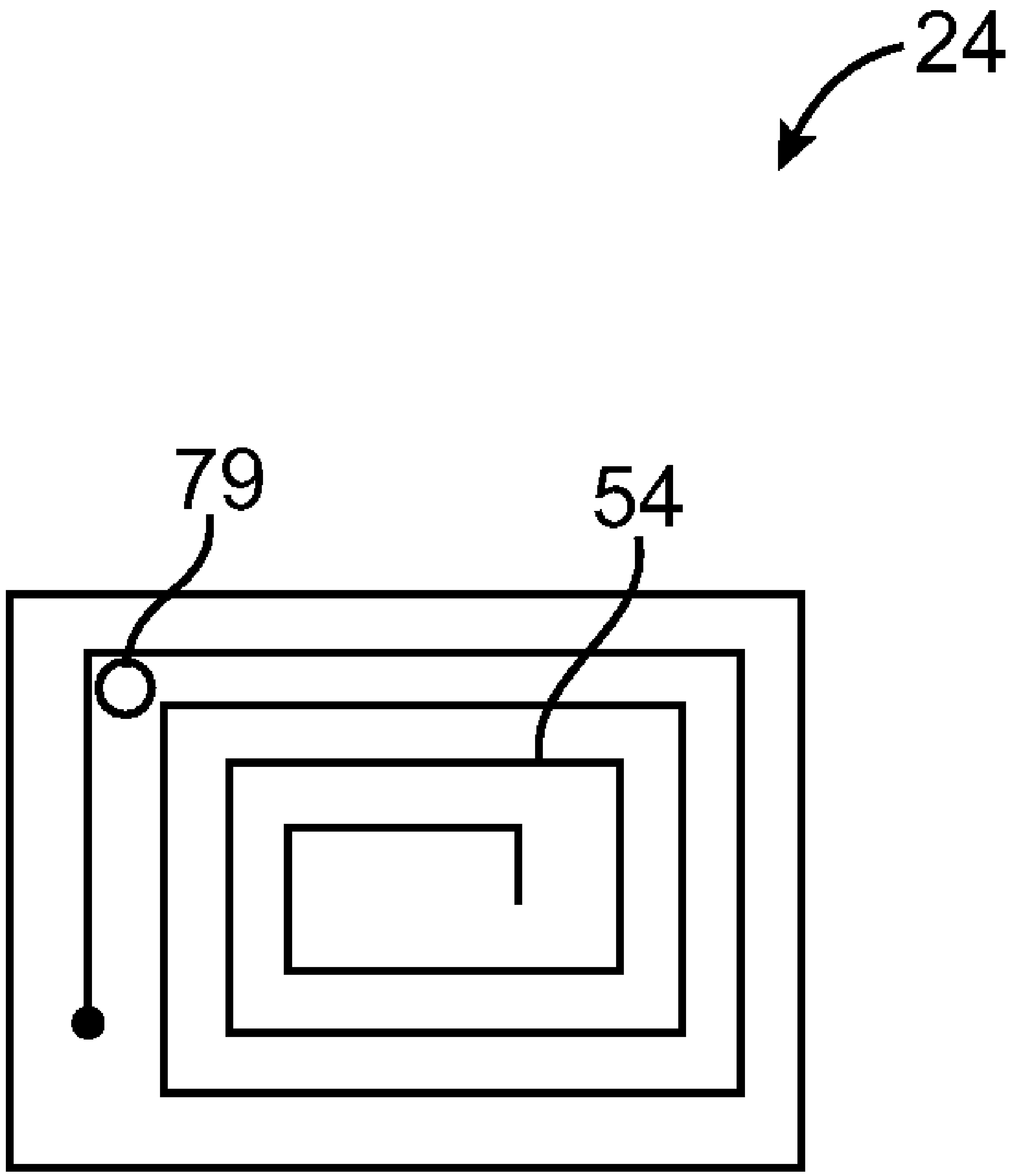


FIG. 7

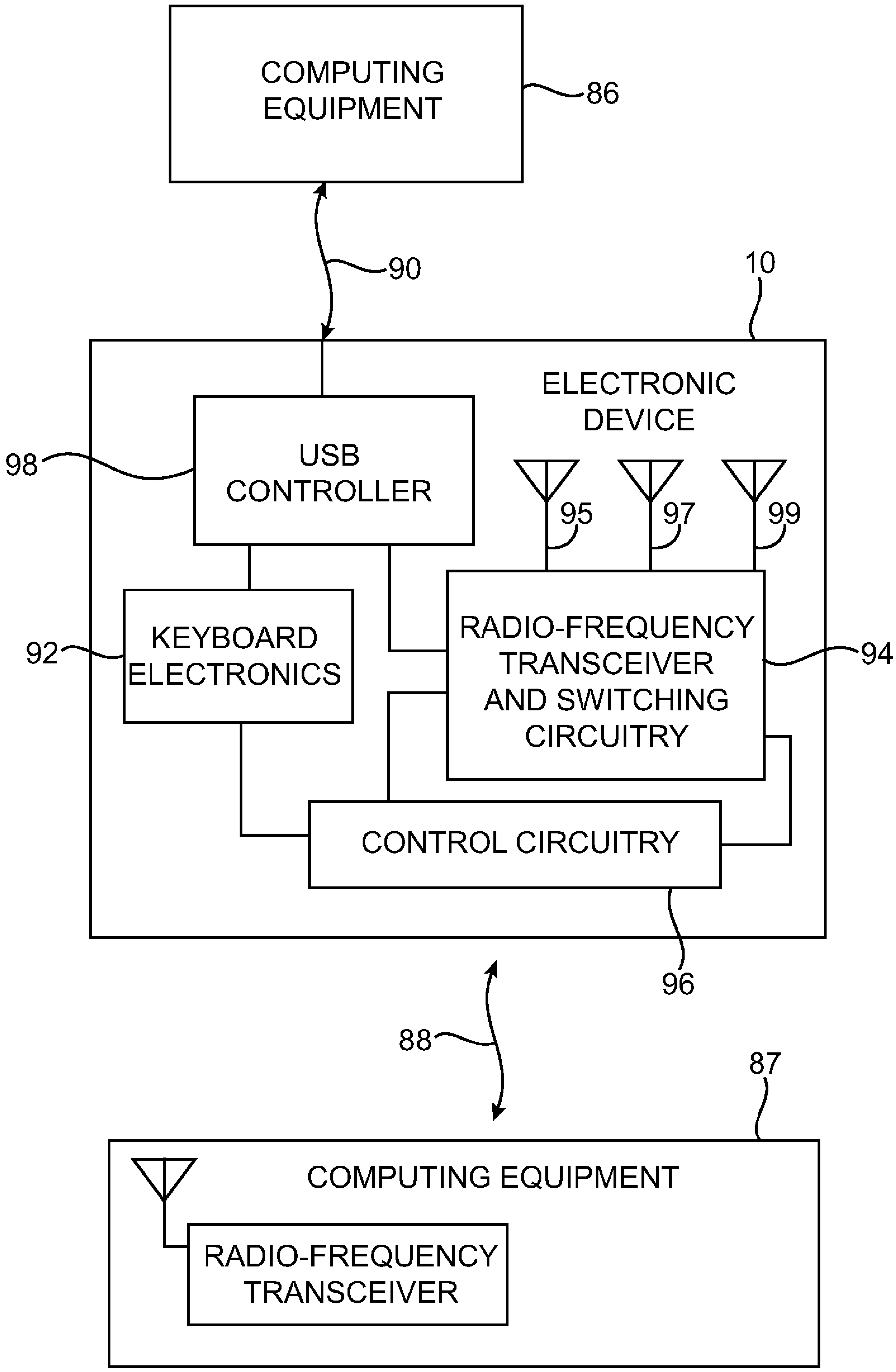

COMPUTING
EQUIPMENT
86
90
10
ELECTRONIC
DEVICE
98
USB
CONTROLLER
95
97
99
92
KEYBOARD
ELECTRONICS
RADIO-FREQUENCY
TRANSCEIVER
AND SWITCHING
CIRCUITRY
94
CONTROL CIRCUITRY
96
88
87
COMPUTING EQUIPMENT
RADIO-FREQUENCY
TRANSCEIVER

FIG. 8

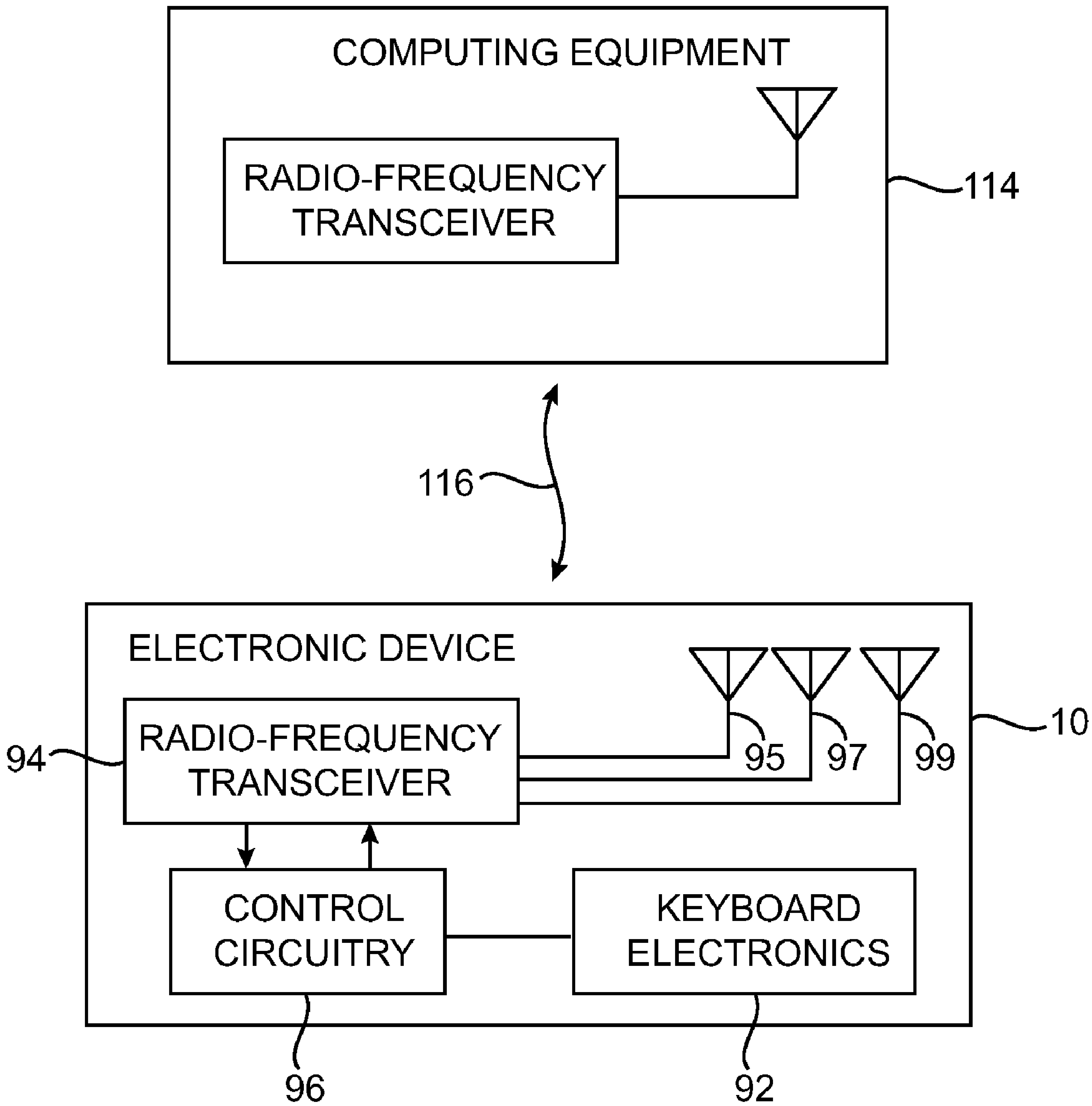

COMPUTING EQUIPMENT
RADIO-FREQUENCY TRANSCEIVER
114
116
ELECTRONIC DEVICE
RADIO-FREQUENCY TRANSCEIVER
94
95
97
99
10
CONTROL CIRCUITRY
KEYBOARD ELECTRONICS
96
92

FIG. 9

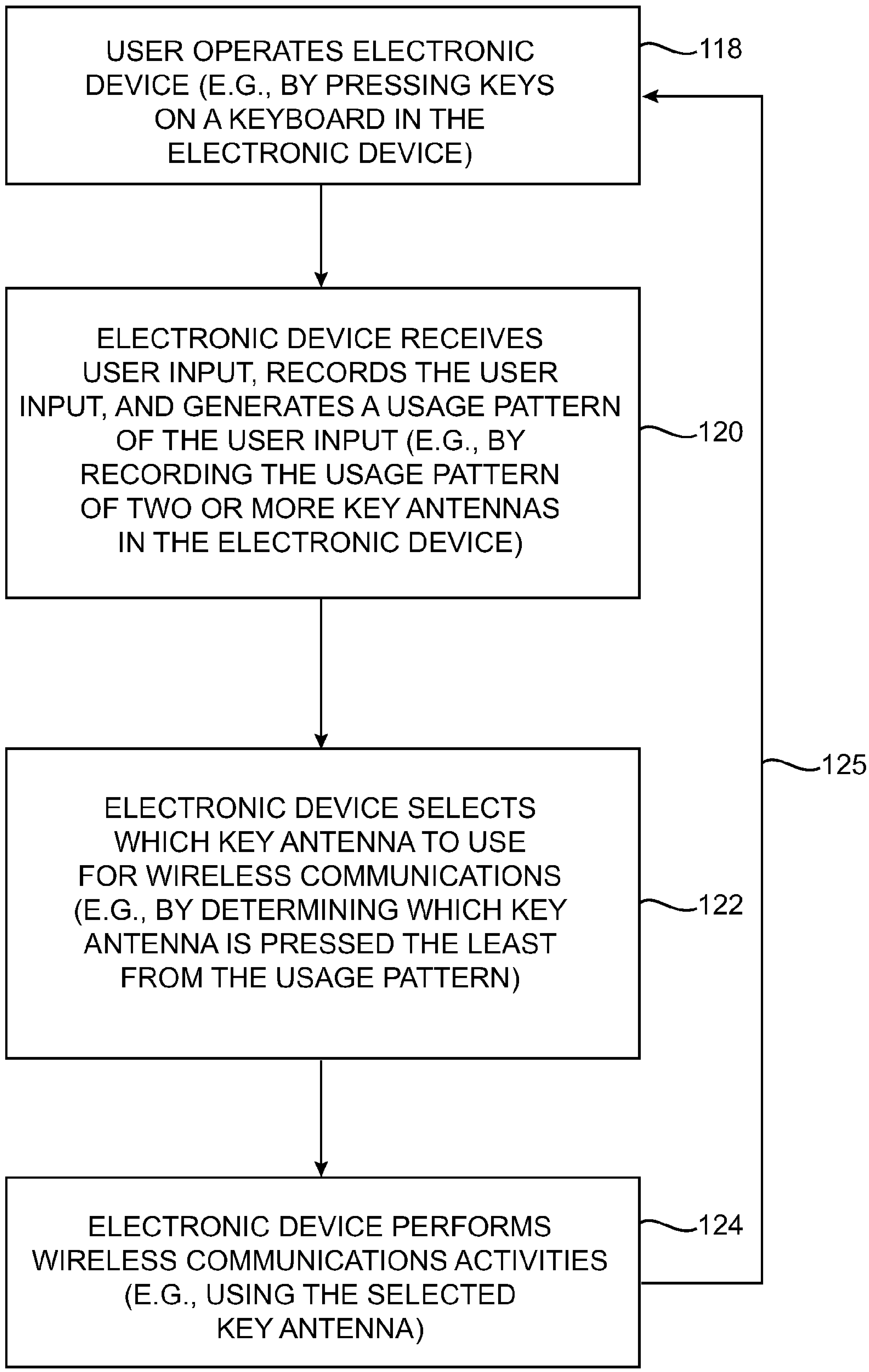

USER OPERATES ELECTRONIC DEVICE (E.G., BY PRESSING KEYS ON A KEYBOARD IN THE ELECTRONIC DEVICE)
118
ELECTRONIC DEVICE RECEIVES USER INPUT, RECORDS THE USER INPUT, AND GENERATES A USAGE PATTERN OF THE USER INPUT (E.G., BY RECORDING THE USAGE PATTERN OF TWO OR MORE KEY ANTENNAS IN THE ELECTRONIC DEVICE)
120
ELECTRONIC DEVICE SELECTS WHICH KEY ANTENNA TO USE FOR WIRELESS COMMUNICATIONS (E.G., BY DETERMINING WHICH KEY ANTENNA IS PRESSED THE LEAST FROM THE USAGE PATTERN)
122
125
ELECTRONIC DEVICE PERFORMS WIRELESS COMMUNICATIONS ACTIVITIES (E.G., USING THE SELECTED KEY ANTENNA)
124

FIG. 10

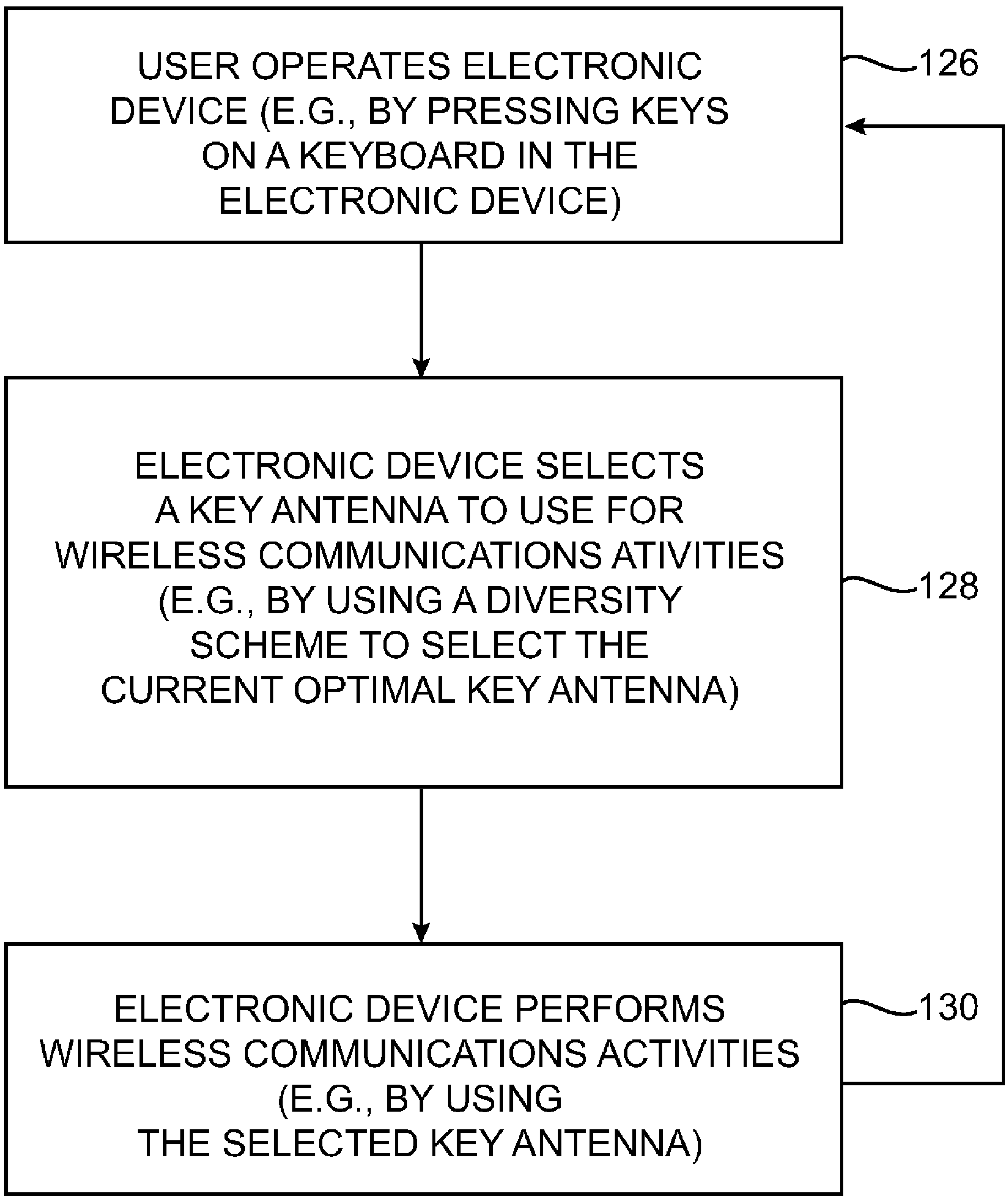

USER OPERATES ELECTRONIC DEVICE (E.G., BY PRESSING KEYS ON A KEYBOARD IN THE ELECTRONIC DEVICE)
126
ELECTRONIC DEVICE SELECTS A KEY ANTENNA TO USE FOR WIRELESS COMMUNICATIONS ATIVITIES (E.G., BY USING A DIVERSITY SCHEME TO SELECT THE CURRENT OPTIMAL KEY ANTENNA)
128
ELECTRONIC DEVICE PERFORMS WIRELESS COMMUNICATIONS ACTIVITIES (E.G., BY USING THE SELECTED KEY ANTENNA)
130

FIG. 11

ANTENNAS FOR ELECTRONIC DEVICES

BACKGROUND

This invention relates to antennas, and more particularly, to antennas for electronic devices.

It may be desirable to include wireless communications capabilities in an electronic device. Electronic devices may use wireless communications to communicate with wireless base stations. For example, electronic devices may communicate using the Wi-Fi® (IEEE 802.11) bands at 2.4 GHz and 5.0 GHz and the Bluetooth® band at 2.4 GHz. Electronic devices may also use other types of communications links.

Many popular housing materials for electronic devices such as metal have a high conductivity. This poses challenges when designing an antenna for an electronic device with this type of housing. An internal antenna would be shielded by a high-conductivity housing, so internal antenna designs are often not considered practical in electronic devices with conductive cases. On the other hand, external antenna designs that permanently protrude from a device's housing may have an unattractive appearance. Conventional protruding antenna designs may also be susceptible to damage.

It would therefore be desirable to be able to provide improved antennas for electronic devices.

SUMMARY

In accordance with an embodiment of the present invention, antennas for electronic devices are provided.

An electronic device may have a keyboard. One or more of the keys of the keyboard may be key antennas. For example, one of more of the keys of the keyboard may have antennas integrated into their structure to provide the electronic device with wireless communications functionality.

A key antenna may have an antenna resonating element. The antenna resonating element in the key antenna may be formed using any suitable antenna design. For example, the antenna resonating element may be formed from a flex circuit containing a strip of conductor, a piece of stamped metal foil, a length of wire, etc. The antenna resonating element may be mounted to the underside of a keycap of the key antenna. The antenna resonating element may be integrated into the keycap of the key antenna. The keycap may have a representation of the function of the key. For example, the keycap may indicate to a user that the key is a caps lock key.

The electronic device may have a conductive housing. The key antenna may have improved transmission and reception efficiencies when the key antenna is away from the conductive housing of device **10**. For example, the key antenna may have improved transmission and reception efficiencies when the key antenna is not being pressed by a user. In this position, the key antenna's performance may be enhanced by the increase in separation (e.g., compared to the position when the key is pressed) between the antenna resonating element in the key antenna and the ground plane of the conductive housing of the electronic device.

The key antenna may also have an indicator light. The indicator light may include a light source that illuminates a translucent portion of the keycap. The electronic device may use the indicator light to indicate a state of the electronic device that is controlled by the key. For example, the indicator light may indicate whether the caps lock function is active. The indicator light may switch on or off when the user presses the key. With another suitable arrangement, the indicator light may switch on while the user is pressing the key and switch off when the user is not pressing the key.

The electronic device may have a radio-frequency transceiver. The radio-frequency transceiver may be coupled to the antenna resonating element in the keycap of the key antenna. The antenna resonating element may be coupled to the transceiver through a weak spring that flexes as the key is pressed by a user. The antenna resonating element may be coupled to the transceiver through a flexible communications path that flexes into the electronic device as the key is pressed by the user.

The electronic device may provide wireless communications capabilities to otherwise non-wireless devices. The electronic device may also provide keyboard input for non-wireless devices. For example, the electronic device may be coupled to a non-wireless device through a wired universal serial bus interface. The electronic device may provide the non-wireless device with wireless communications capabilities when the radio-frequency transceiver in the electronic device is coupled to the non-wireless device over the wired interface.

The electronic device may provide keyboard input for wireless devices and may extend the wireless capabilities of the wireless devices. For example, the electronic device may wirelessly couple to a wireless device to provide the wireless device with keyboard input capabilities. The electronic device may support wireless communications in additional radio-frequency (RF) bands that are not supported by the wireless device. The electronic device may extend the wireless communications capabilities of the wireless device to include the additional RF bands by relaying wireless communications for the additional RF bands through one or more RF bands that both the electronic device and the wireless device support.

Further features of the invention, its nature and various advantages will be more apparent from the accompanying drawings and the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a cross-sectional view of a conventional key.

FIG. **2** is an overhead view of an illustrative electronic device with illustrative key antennas in accordance with an embodiment of the present invention.

FIG. **3** is an overhead view of an illustrative electronic device with illustrative key antennas in accordance with an embodiment of the present invention.

FIG. **4** is a schematic diagram of an illustrative electronic device in accordance with an embodiment of the present invention.

FIG. **5** is a cross-sectional side view of an illustrative key antenna in an illustrative electronic device in accordance with an embodiment of the present invention.

FIG. **6** is a cross-sectional side view of an illustrative key antenna with a weak spring in an illustrative electronic device in accordance with an embodiment of the present invention.

FIG. **7** is a cross-sectional top view of an illustrative keycap that may be part of an illustrative key antenna in an electronic device in accordance with an embodiment of the present invention.

FIG. **8** is a generalized schematic diagram of illustrative computing equipment and an illustrative electronic device that may have key antennas in accordance with an embodiment of the present invention.

FIG. **9** is a generalized schematic diagram of illustrative computing equipment and an illustrative electronic device that may have key antennas in accordance with an embodiment of the present invention.

FIG. **10** is a flow chart of illustrative steps involved in using an electronic device that utilizes a usage pattern to select a key antenna to perform wireless communications activities in accordance with an embodiment of the present invention.

FIG. **11** is a flow chart of illustrative steps involved in using an electronic device that utilizes real-time information to select a key antenna to perform wireless communications activities in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION

This invention relates to antennas, and more particularly, to key antennas for wireless electronic devices.

The wireless electronic devices may be any suitable electronic devices. As an example, the wireless electronic devices may be laptop computers or other computer equipment. The wireless electronic devices may also be portable electronic devices such as wireless keyboards. With one suitable arrangement, the portable electronic devices may be handheld electronic devices. These are merely illustrative examples.

A conventional key such as key **100** that may be a part of a keyboard in an electronic device is shown in FIG. **1**. Key **100** may include a keycap such as keycap **102** that includes a representation of a key. For example, keycap **102** may have a representation such as "Fn", "A", "Tab" "Alt", "Ctrl", "F", "Esc", "Caps Lock", "Num Lock", a menu symbol, an arrow symbol, or any other key that may be represented in a keyboard for an electronic device. With one suitable arrangement, the representation on a key may include a symbol representing the manufacturer of the software or hardware of the electronic device.

Key **100** may be a part of a keyboard. In the FIG. **1** example, key **100** is supported by a scissor-arm mechanism. Scissor-arm mechanism **100** may keep keycap **102** level and parallel to the base of the keyboard as key **100** is pressed. Scissor-arm mechanism **100** may also prevent keycap **102** from twisting when the key is pressed.

Key **100** may also include a dome-switch to provide tactile feedback to a user. For example, dome-switch **106** may include portions such as portions **107** that collapse when key **100** is pressed. Dome-switch **106** may have portions such as portion **108** that push against membrane **110** when the key is pressed. As portion **108** presses against membrane **110**, membrane **110** may contact with and bias against membrane **112**. Membranes **110** and **112** may be formed from conductive materials or may be coated with conductive materials such as conductive ink. When key **100** is pressed and membranes **110** and **112** come into contact with each other, an electrical signal associated with key **100** that indicates the key has been pressed may be generated and picked up by electronics in the electronic device.

An illustrative electronic device that may have key antennas is shown in FIG. **2**. Device **10** may be any suitable electronic device. For example, device **10** may be a laptop computer or a wireless keyboard.

Device **10** may handle communications over one or more communications bands. For example, wireless communications circuitry in device **10** may be used to handle data communications bands such as the 2.4 GHz band that is sometimes used for Wi-Fi® (IEEE 802.11) and Bluetooth® communications, the 5.0 GHz band that is sometimes used for Wi-Fi communications, the 1575 MHz Global Positioning System band, and 3G data bands (e.g., the UMTS band at 1920-2170). These bands may be covered by using single band and multiband antennas. For example, cellular telephone communications can be handled using a multiband cellular telephone antenna and local area network data communications can be handled using a multiband wireless local area network antenna. As another example, device **10** may have a single multiband antenna for handling communications in two or more data bands (e.g., at 2.4 GHz and at 5.0 GHz).

Device **10** may have housing **12**. Housing **12**, which is sometimes referred to as a case, may be formed of any suitable materials including plastic, glass, ceramics, metal, other suitable materials, or a combinations of these materials.

Housing **12** or portions of housing **12** may also be formed from conductive materials such as metal. An illustrative metal housing material that may be used is anodized aluminum. Aluminum is relatively light in weight and, when anodized, has an attractive insulating and scratch-resistance surface. If desired, other metals can be used for the housing of device **10**, such as stainless steel, magnesium, titanium, alloys of these metals and other metals, etc. In scenarios in which housing **12** is formed from metal elements, one or more of the metal elements may be used as part of the antenna in device **10**. For example, metal portions of housing **12** and metal components in housing **12** may be shorted together to form a ground plane in device **10** or to expand a ground plane structure that is formed from a planar circuit structure such as a printed circuit board structure (e.g., a printed circuit board structure used in forming antenna structures for device **10**).

Device **10** may have one or more buttons (keys) such as buttons **14**. Buttons **14** may be formed on any suitable surface of device **10**. In the example of FIG. **2**, buttons **14** have been formed on the top surface of device **10**. As an example, buttons **14** may form a keyboard on a laptop computer.

If desired, device **10** may have a display such as display **16**. Display **16** may be a liquid crystal diode (LCD) display, an organic light emitting diode (OLED) display, a plasma display, or any other suitable display. The outermost surface of display **16** may be formed from one or more plastic or glass layers. If desired, touch screen functionality may be integrated into display **16**. Device **10** may also have a separate touch pad device such as touch pad **20**. An advantage of integrating a touch screen into display **16** to make display **16** touch-sensitive is that this type of arrangement can save space and reduce visual clutter. Buttons **14** may, if desired, be arranged adjacent to display **16**. With this type of arrangement, the buttons may be aligned with on-screen options that are presented on display **16**. A user may press a desired button to select a corresponding one of the displayed options.

Device **10** may have circuitry **18**. Circuitry **18** may include storage, processing circuitry, and input-output components. Wireless transceiver circuitry in circuitry **18** may be used to transmit and receive radio-frequency (RF) signals. Communications paths such as coaxial communications paths and microstrip communications paths may be used to convey radio-frequency signals between transceiver circuitry and antenna structures in device **10**. As shown in FIG. **2**, for example, communications path **22** may be used to convey signals between antenna structure **24** and circuitry **18**. Communications paths **26** and **30** may be used to convey signals between antenna structures **28** and **32**, respectively. Each communications path may be, for example, a coaxial cable that is connected between an RF transceiver (sometimes called a radio) and a multiband antenna (e.g., a multiband key antenna).

Antenna structures such as antenna structures **24** and **28** may be integrated into keys (e.g., buttons **14**) of device **10**. The antenna structures may be integrated into keys that are not typically pressed by a user. For example, the antenna structures may be integrated into keys such as the "Pause/Break" key, the "Esc" key, or another suitable key. With one suitable example, there may be two antenna structures (e.g., structures **24** and **28**) that are integrated into two separate keys that are rarely pressed simultaneously or that are in opposite corners of the keyboard. Device **10** may also have an antenna structure such as antenna structure **32** that is not integrated into a key.

Device **10** may be able to sense when a key antenna (e.g., antenna structure that is built into a key) is pressed by a user and to utilize a different antenna when the key antenna is pressed. For example, when a user presses key antenna **24**, device **10** may determine from its keyboard input or from reduced antenna performance that key antenna has been pressed. Device **10** may therefore deactivate key antenna **24** and may active key antenna **28** or antenna structure **32** to maintain wireless communications functionality for the electronic device.

Antenna structures such as antenna structures **24** and **28** (e.g., key antennas) may have antenna resonating elements that are integrated into portions of keys that rise above the housing of the electronic device. For example, antenna resonating elements may be integrated into a keycap or into the support mechanisms (e.g., a scissor-arm mechanism) of a key. Key antennas of this type may be used to increase the efficiency of signal reception and transmission. For example, when device **10** includes a housing such as housing **12** that is formed from conductive materials, antenna structures **24** and **28** may enhance wireless communications functionality by increasing the separation between the ground plane of device **10** and antenna resonating elements in antenna structures **24** and **28** without resorting to conventional external antenna designs that have unsightly protrusions.

FIG. **3** shows an illustrative electronic device such as electronic device **10** that may have key antennas. Device **10** may be a wireless keyboard such as keyboard **52** that wirelessly connects to nearby computing equipment or electronic devices (e.g., desktop computers). Keyboard **52** may have all of the features described in connection with device **10** except that a display such as display **16** or a touchpad such as touchpad **20** may be optional in keyboard **52**.

With another suitable arrangement, device **10** may be based on a wired keyboard such as keyboard **52** that provides wireless communications functionality to computing equipment (e.g., another electronic device). For example, keyboard **52** may connect to computing equipment (e.g., an electronic device) such as a desktop computer through a conventional universal serial bus interface. The computing equipment may be able to transmit and receive radio-frequency signals using keyboard **52**. For example, antennas and radio-frequency transceivers in keyboard **52** may be coupled to the computing equipment by the universal serial bus interface.

A schematic diagram of an embodiment of electronic device **10** is shown in FIG. **4**. Electronic device **10** may be a notebook computer, a wireless keyboard, a wired keyboard, a tablet computer, an ultraportable computer, a handheld computer, a remote control, a game player, a global positioning system (GPS) device, a combination of such devices, or any other suitable portable or handheld electronic device.

As shown in FIG. **4**, electronic device **10** may include storage **34**. Storage **34** may include one or more different types of storage such as hard disk drive storage, nonvolatile memory (e.g., flash memory or other electrically-programmable-read-only memory), volatile memory (e.g., battery-based static or dynamic random-access-memory), etc.

Processing circuitry **36** may be used to control the operation of device **10**. Processing circuitry **36** may be based on a processor such as a microprocessor and other suitable integrated circuits. With one suitable arrangement, processing circuitry **36** and storage **34** are used to run software on device **10**, such as internet browsing applications, voice-over-internet-protocol (VOIP) telephone call applications, email applications, media playback applications, operating system functions, etc. Processing circuitry **36** and storage **34** may be used in implementing suitable communications protocols. Communications protocols that may be implemented using processing circuitry **36** and storage **34** include internet protocols, wireless local area network protocols (e.g., IEEE 802.11 protocols—sometimes referred to as Wi-Fi®), protocols for other short-range wireless communications links such as the Bluetooth® protocol, protocols for handling 3G data services such as UMTS, cellular telephone communications protocols, etc.

Input-output devices **38** may be used to allow data to be supplied to device **10** and to allow data to be provided from device **10** to external devices. Display screen **16**, keys **14** (e.g., keyboard **14**), and touchpad **20** of FIG. **2** are examples of input-output devices **38**.

Input-output devices **38** may include user input-output devices **40** such as buttons, touch screens, joysticks, click wheels, scrolling wheels, touch pads, key pads, keyboards, microphones, cameras, speakers, tone generators, vibrating elements, etc. A user can control the operation of device **10** by supplying commands though user input devices **40**.

Display and audio devices **42** may include liquid-crystal display (LCD) screens or other screens, light-emitting diodes (LEDs), and other components that present visual information and status data. Display and audio devices **42** may also include audio equipment such as speakers and other devices for creating sound. Display and audio devices **42** may contain audio-video interface equipment such as jacks and other connectors for external headphones and monitors.

Wireless communications devices **44** may include communications circuitry such as radio-frequency (RF) transceiver circuitry formed from one or more integrated circuits, power amplifier circuitry, passive RF components, one or more antennas (e.g., antenna structures such as antenna structures **24**, **28**, and **32** of FIG. **2**), and other circuitry for handling RF wireless signals. Wireless signals can also be sent using light (e.g., using infrared communications).

Device **10** can communicate with external devices such as accessories **46** and computing equipment **48**, as shown by paths **50**. Paths **50** may include wired and wireless paths. Accessories **46** may include headphones (e.g., a wireless headset or audio headphones) and audio-video equipment (e.g., wireless speakers, a game controller, or other equipment that receives and plays audio and video content).

Computing equipment **48** may be any suitable computer. With one suitable arrangement, computing equipment **48** is a computer that has an associated wireless access point or an internal or external wireless card that establishes a wireless connection with device **10**. The computer may be a server (e.g., an internet server), a local area network computer with or without internet access, a user's own personal computer, a peer device (e.g., another electronic device **10**), or any other suitable computing equipment.

The antenna structures and wireless communications devices of device **10** may support communications over any suitable wireless communications bands. For example, wireless communications devices **44** may be used to cover communications frequency bands such as the cellular telephone bands at 850 MHz, 900 MHz, 1800 MHz, and 1900 MHz, data service bands such as the 3G data communications band at 2100 MHz (commonly referred to as UMTS or Universal

Mobile Telecommunications System), Wi-Fi® (IEEE 802.11) bands at frequencies such as 2.4 GHz and 5.0 GHz (also sometimes referred to as wireless local area network or WLAN bands), the Bluetooth band at 2.4 GHz, and the global positioning system (GPS) band at 1575 MHz. Device **10** can cover these communications bands and/or other suitable communications bands with proper configuration of the antenna structures in wireless communications circuitry **44**.

An illustrative key antenna that may be a part of an electronic device such as device **10** is shown in FIG. **5**. Antenna structure **24** may be integrated into the structure of a key that is part of a keyboard in device **10** (as an example).

Antenna structure **24** may exhibit improved transmission and reception efficiencies when the antenna structure is located away from the conductive housing of device **10** (e.g., when the key is not being pressed by a user). In this extended position, the antenna's performance may be enhanced by the increase in separation (e.g., compared to the position when the key is pressed) between an antenna resonating element in the antenna and the ground plane of the metal housing of the electronic device.

Antenna structure **24** may have a keycap such as keycap **62** that includes a representation of a key. For example, keycap **62** may have a representation such as "Fn", "A", "Tab" "Alt", "Ctrl", or any other key that may be represented in a keyboard or other keypad of an electronic device. With one suitable arrangement, antenna structure **24** may be integrated into a key that is not commonly pressed by a user of device **10** such as the print screen key.

Antenna structure **24** (key antenna **24**) may be a part of a keyboard that utilizes any suitable keyboard technology. For example, the keyboard may be based on keyboard technologies such as dome-switch, scissor-switch, capacitive, mechanical-switch, buckling-spring, Hall-effect, laser and membrane keyboard technologies. In the FIG. **5** example, key antenna **24** is supported by a scissor-arm mechanism. Scissor-arm mechanism **64** may keep keycap **62** level and parallel to the base of the keyboard as key antenna **24** is pressed by a user. Scissor-arm mechanism **64** may also prevent keycap **62** from twisting when the key (e.g., key antenna **24**) is pressed.

Key antenna **24** may include a dome-switch to provide tactile feedback to a user. For example, rubber dome-switch **66** may include portions such as portions **70** that collapse when key antenna **24** is pressed. Dome-switch **66** may have portions such as portion **68** that push against membrane **72** when the key is pressed. As portion **68** presses against membrane **72**, membrane **72** may contact with and bias against membrane **74**. Membrane **73** may be a dielectric membrane that separates membranes **72** and **74**. Membrane **73** may have holes located under each portion **68** so that membranes **72** and **74** may contact each other when the key is pressed. Membranes **72** and **74** may be formed from conductive materials or may be coated with conductive materials such as a conductive ink. When key antenna **24** is pressed and membranes **72** and **74** come into contact with each other, an electrical signal associated with key antenna **24** that indicates the key has been pressed may be generated and picked up by electronics in electronic device **10**.

Key antenna **24** may have antenna resonating element **54**. Antenna resonating element **54** may be formed using any suitable antenna design. For example, the antenna resonating element may be formed from a flex circuit containing a strip of conductor, a piece of stamped metal foil, a length of wire, etc. Radio-frequency signals may pass through keycap **62** to an antenna resonating element (e.g., element **54**) that may be affixed to the bottom of keycap **62**. With one suitable arrangement, antenna resonating element **54** may be integrated into keycap **62**. For example, antenna resonating element **54** may be formed from a spirally wrapped length of wire that is embedded in the material of keycap **62**.

Antenna structure **24** may have portions such as portion **60** that carry a communications path or a portion of an antenna resonating element through an opening in device **10**. For example, portion **60** may carry communications path **56** from inside device **10** to antenna resonating element **54** outside device **10** through an opening in housing **12**. With one suitable arrangement, portion **60** may be formed as part of an antenna resonating element such as antenna resonating element **54**.

Circuitry **18** (e.g., a radio-frequency transceiver in device **10**) may be electrically coupled to antenna resonating element **54** in key antenna **24** through communications paths **22** and **56** and through coupling structure **58**. Circuitry **18** may transmit and receive radio-frequency signals using antenna resonating element **54** as one pole of an antenna. Circuitry **18** may utilize a separate ground plane for the antenna by grounding to a metal structure such as housing **12**.

Coupling structure **58** may be used to couple together communications paths **22** and **56**. Communications path **22** may be based on a coaxial cable with an inner conductor and an outer conductor. Coupling structure **58** may ground the outer conductor of path **22** to housing **12** of device **10**. Coupling structure **58** may couple the inner conductor from path **22** to an inner or positive conductor associated with communications path **56**. Tuning elements **76** may be used to tune the electrical coupling between communications paths **22** and **56**. Tuning elements **76** may be formed from any suitable elements such as resistors, inductors, capacitors, transistors, etc.

Communications path **56** may flex when key antenna structure **24** is pressed by a user of the electronic device. For example, communications path **56** may be a flex circuit and, as key antenna **24** is pressed, communications path **56** may flex into the position illustrated by line **57** to accommodate the movement of key antenna **24**.

Key antenna **24** may have an indicator light with a light source **78** that emits light through a portion of keycap **62** such as portion **79**. Light **78** may be an indicator light for a key in device **10**. For example, light **78** may indicate whether a caps lock function is active (e.g., by lighting up a portion of the caps lock key). Light **78** may be any suitable light source such as a light emitting diode (LED) or an incandescent light bulb. Portion **79** may be a transparent or translucent portion of keycap **62**. Portion **79** may be a hole in keycap **62** that passes light from light **78**.

As illustrated by FIG. **6**, key antenna **24** may have a spring such as spring **82** that provides feedback to a user when the user presses the key antenna. Spring **82** may be a part of antenna resonating element **54** or may be used as part of a communications path that couples the antenna resonating element to coupling structure **80**. For example, antenna resonating element **54** may be partially or entirely formed from spring **82**. With one suitable arrangement, spring **82** may be a weak spring that serves to couple antenna resonating element **54** to coupling structure **80** without altering the operation of the key (e.g., so that a user pressing the key may be unable to tell that the key includes spring **82**). Scissor-arm mechanism **64** is not shown in FIG. **6** for the sake of reducing visual clutter. However, scissor-arm mechanism **64** may be a part of the key antenna shown in FIG. **6**.

Coupling structure **80** may be used to couple communications path **22** to communications path **84**, spring **82**, and antenna resonating element **54**. Coupling structure **80** may couple an inner conductor in communications path **22** to an inner conductor in communications path **84** (e.g., when paths

22 and **84** are coaxial cables). Coupling structure **80** may couple a ground conductor in communications path **82** to housing **12** (e.g., a ground plane in device **10**). Coupling structure **80** may be any suitable radio-frequency connector such as a miniature or sub-miniature connector.

As shown in FIG. **7**, key antenna **24** may have a spirally wrapped antenna resonating element. For example, antenna resonating element **54** may be spirally wrapped and affixed to the bottom of a keycap of key antenna **24**. With another suitable arrangement, antenna resonating element **54** may be spirally wrapped and integrated into the structure of the keycap of key antenna **24**. For example, the antenna resonating element may be formed from a spirally wrapped wire that is embedded in the plastic of keycap **62**. Portion **79** may represent a translucent section of the keycap that is lit by light **78** to indicate information about device **10** to a user (e.g., whether caps lock is active).

An illustrative environment in which electronic device **10** may be used with wired and wireless computing equipment such as computing equipment **86** and **87** is shown in FIG. **8**. Computing equipment **86** may be computing equipment (e.g., a second electronic device such as a desktop computer) that does not have wireless communications functionality. Electronic device **10** may be a wired keyboard that provides computing equipment **86** with wireless communications functionality. Electronic device **10** may also act as a conventional keyboard input device for equipment **86**. Electronic device **10** may be coupled to computing equipment **86** through a communications path. The communications path may be formed using any suitable communications arrangement. For example, device **10** may be coupled to equipment **86** through a universal serial bus interface such as interface **90** (e.g., a universal serial bus cable). Computing equipment **86** may have one or more universal serial bus ports. With one suitable arrangement, device **10** may have a USB cable that couples to a USB port in computing equipment **86**.

Device **10** may provide computing equipment **86** with both keyboard functionality and wireless communications functionality. For example, universal serial bus (USB) controller **98** may couple computing equipment **86** to a radio-frequency transceiver such as transceiver **94** in device **10** over USB interface **90** (e.g., a USB cable). Device **10** may exchange electrical signals over interface **90** with equipment **86**. The electrical signals may correspond to radio-frequency signals that are generated and received by radio-frequency transceiver **94**. Equipment **86** may use the radio-frequency transceiver of device **10** to perform wireless communications activities (e.g., to send and receive radio-frequency signals).

Device **10** may provide keyboard input for computing equipment **86**. For example, keys that are part of a keyboard in device **10** may provide an opportunity for a user to provide input for computing equipment **86**. Keyboard electronics **92** may receive user input generated through the keyboard of device **10**. Keyboard electronics **92** may relay the signals corresponding to user input on the keyboard to computing equipment **86** through USB controller **98** and USB interface **90**.

Computing equipment **86** may wirelessly communicate with computing equipment **87** over a wireless communications link such as link **88** that is provided by electronic device **10**. Computing equipment **86** may use radio-frequency transceiver **94** and antennas in device **10** to transmit and receive radio-frequency signals (e.g., to wirelessly communicate with a RF transceiver in equipment **87**).

Electronic device **10** may have control circuitry **96**. When electronic device **10** has more than one key antenna such as key antennas **95**, **97**, and **99**, control circuitry **96** and transceiver and switching circuitry **94** may select a particular key antenna for use in transmitting and receiving radio-frequency signals. For example, control circuitry **96** may be used in implementing an antenna diversity scheme that selects which of multiple key antennas to use in real-time. With one suitable arrangement, control circuitry **96** may select the key antenna that is receiving the strongest radio-frequency signal for use in transmitting and receiving radio-frequency signals.

In another example, control circuitry **96** may select which key antenna to use based on the historical usage (e.g., numbers of times the key has been pressed) of the key antennas in device **10**. For example, when device **10** has two key antennas, control circuitry **96** may maintain a record of the number of times each key antenna is pressed by the user and may select the least pressed key antenna to use in transmitting and receiving radio-frequency signals.

In another example, when device **10** is using a first key antenna for wireless communications, control circuitry **96** may select a second key antenna when the first key antenna is pressed. Control circuitry **96** may receive signals from keyboard electronics **92** when a particular key antenna is pressed indicating that the particular key antenna has been pressed. Transceiver and switching circuitry **94** (e.g., a radio-frequency transceiver) may receive signals from control circuitry **96** that indicate which key antenna is to be used and may switch to the selected key antenna based on those signals.

A diagram of electronic device **10** in wireless communications with computing equipment **114** is shown in FIG. **9**. Device **10** may be a wireless keyboard that provides keyboard input functionality to computing equipment **114**. Device **10** may communicate with computing equipment **114** over a wireless communications path such as path **116** (e.g., using transceiver **94** and one or more of key antennas **95**, **97**, and **99** to communicate with an antenna and a transceiver in computing equipment **114**).

With one suitable arrangement, electronic device **10** may extend the wireless communications capabilities of computing equipment **114**. For example, electronic device **10** may support a first communications band (e.g., for communications with computing equipment **114**) that is also supported by computing equipment **114** and a second communications band that is not supported by computing equipment **114**. Device **10** may allow computing equipment **114** to wirelessly communicate with other electronic devices in the second communications band by relaying wireless signals corresponding to the second band between device **10** and equipment **114** over the first communications band (e.g., over link **116**).

Illustrative steps involved in using an electronic device with key antennas such as key antennas **24** and **28** are shown in FIG. **10**. The operations of FIG. **10** may be performed when the electronic device (e.g., device **10**) is configured to select the least pressed key antenna (e.g., out of two or more key antennas) for use in wireless communications activities.

As shown in FIG. **10**, a user may operate the electronic device at step **118**. The user may operate the electronic device by, for example, pressing keys on a keyboard in device **10** (e.g., a keyboard formed from buttons **14** or a keyboard such as keyboard **52**).

After the user presses one or more keys in device **10** in step **118**, electronic device **10** may receive the user input (e.g., key presses) and may record the user input at step **120**. Electronic device **10** may generate a usage pattern of the user input from the electronic device's records of the user input. For example, by recording the total number of times particular key antennas are pressed by the user, the electronic device may generate a usage pattern that indicates which key antenna is pressed the least by the user.

At step **122**, electronic device **10** may select a key antenna to use for wireless communications activities. With one suitable arrangement, electronic device **10** may select the least pressed key antenna. For example, device **10** may determine which key antenna is the least pressed using the usage pattern of device **10** (e.g., the key antenna keystroke history). The least pressed key antenna may be the key antenna that has been pressed a minimum number of times by the user. For example, the least pressed key may be the key antenna that is least pressed by the user (at least within a given period of time) and therefore may be the least likely to be pressed by the user during subsequent operation of device **10**.

At step **124**, electronic device **10** may perform wireless communications activities. For example, the electronic device may transmit and receive radio-frequency signals using the key antenna that was selected as being the least frequently pressed in step **122**. By selecting the least frequently pressed key antenna, electronic device **10** may enhance the likelihood that the key antenna will be in position for the transmission and reception of radio-frequency signals (e.g., in an extended position such as when the key antenna is not being pressed and blocked by a user's finger).

As indicated by line **125**, device **10** may continually updates its records on which keys are least frequently pressed by looping back to step **118** (and therefore step **120**).

FIG. **11** shows illustrative steps involved in using an electronic device that utilizes real-time information to select which of multiple key antennas to use for wireless communications activities. The operations of FIG. **11** may be performed when the electronic device (e.g., device **10**) is configured to use a diversity scheme to select a particular key antenna out of a plurality of key antennas for use in wireless communications activities. For example, electronic device **10** may use a diversity scheme in which the key antenna that has the strongest signal (e.g., the antenna that is receiving the strongest radio-frequency signal from another device) is used to transmit and receive radio-frequency signals.

A user may operate the electronic device at step **126** by, for example, pressing keys on a keyboard in device **10** (e.g., a keyboard formed from buttons **14** or a keyboard such as keyboard **52**).

At step **128** the electronic device may select a key antenna for wireless communications activities. The electronic device may select the key antenna for wireless communications using a diversity scheme in which the key antenna that is receiving the strongest signal is selected to perform wireless communications activities. Because the key antenna that is receiving the strongest signal may change as electronic device **10** is operated (e.g., as the user presses keys or physically moves device **10**), selection of a key antenna for communications will generally be implemented as an ongoing operation. For example, step **128** may occur continually even when there is no user input being received by device **10**.

At step **30**, electronic device **10** may perform wireless communications activities. For example, the electronic device may transmit and receive radio-frequency signals using the key antenna that was selected using the diversity scheme in step **128**. By selecting the key antenna that is receiving the stronger RF signals, key antenna based transmission and reception of radio-frequency signals may be enhanced (e.g., wireless communications).

The foregoing is merely illustrative of the principles of this invention and various modifications can be made by those skilled in the art without departing from the scope and spirit of the invention.

What is claimed is:

1. An electronic device comprising:

a communications path;

a radio-frequency transceiver that generates and receives radio-frequency signals that are conveyed over the communications path; and

a keyboard comprising a plurality of keys, wherein a given one of the keys in the plurality of keys comprises a key antenna and wherein the key antenna comprises an antenna resonating element that is coupled to the radio-frequency transceiver over the communications path.

2. The electronic device defined in claim **1** wherein the given one of the keys further comprises:

a keycap; and

a scissor-arm mechanism that keeps the keycap level when the given one of the keys is pressed by a user.

3. The electronic device defined in claim **2** wherein the given one of the keys further comprises a rubber dome switch and wherein the rubber dome switch comprises portions that collapse when the given one of the keys is pressed by the user.

4. The electronic device defined in claim **1** wherein a state of the electronic device is altered when the given one of the keys is pressed by a user and wherein the given one of the keys further comprises an indicator that indicates the state of the electronic device.

5. The electronic device defined in claim **4** wherein the given one of the keys further comprises a keycap, wherein the keycap comprises portions that define a translucent hole in the keycap, and wherein the indicator comprises a light source that illuminates the translucent hole in the keycap.

6. The electronic device defined in claim **1** wherein the communications path comprises a weak spring that flexes when the given one of the keys is pressed by a user.

7. The electronic device defined in claim **1** wherein the communications path comprises a flex circuit that flexes into the electronic device when the given one of the keys is pressed by a user.

8. The electronic device defined in claim **1** further comprising:

a first membrane;

a second membrane, wherein the given one of the keys further comprises portions that bias the first membrane against the second membrane when the given one of the keys is pressed by a user.

9. The electronic device defined in claim **1** wherein the given one of the keys further comprises a keycap, wherein the antenna resonating element comprises a spirally wrapped wire, and wherein the spirally wrapped wire is integrated into the keycap.

10. The electronic device defined in claim **1** wherein the given one of the keys is a first given key in the plurality of keys, the electronic device further comprising:

at least one additional key antenna in a second given key in the plurality of keys; and

control circuitry that records the number of times each of the first and second given keys has been pressed by a user, wherein the radio-frequency transceiver is configured to transmit and receive radio-frequency signals using the key antenna in the one of the first and second given keys that has been pressed a minimum number of times by the user in a given period of time.

11. The electronic device defined in claim **1** wherein the given one of the keys is a first given key in the plurality of keys, the electronic device further comprising:

at least one additional key antenna in a second given key in the plurality of keys; and

control circuitry that is coupled to the radio-frequency transceiver that determines which key antenna is receiving strongest radio-frequency signals and that directs the radio-frequency transceiver to transmit and receive radio-frequency signals using the key antenna that is receiving the strongest radio-frequency signals.

12. The electronic device defined in claim **1** wherein the electronic device comprises a laptop computer having a processor coupled to the radio-frequency transceiver.

13. The electronic device defined in claim **1** wherein the keyboard comprises a wireless keyboard.

14. The electronic device defined in claim **1** the keyboard comprises a wired keyboard with a universal serial bus cable, the electronic device further comprising:

a desktop computer with a universal serial bus port, wherein the universal serial bus cable and the universal serial bus port convey electrical signals between the wired keyboard and the desktop computer.

15. The electronic device defined in claim **14** wherein the radio-frequency transceiver in the wired keyboard is configured to generate and receive radio-frequency signals for the given one of the keys that correspond to the electrical signals that are conveyed over the universal serial bus cable.

16. A portable computer comprising:

a communications path;

a radio-frequency transceiver that generates and receives radio-frequency signals that are conveyed over the communications path; and

a keyboard comprising a plurality of keys, wherein one of the keys in the plurality of keys comprises a key antenna and wherein the key antenna comprises an antenna resonating element that is coupled to the radio-frequency transceiver over the communications path.

17. The portable computer defined in claim **16** further comprising:

keyboard circuitry that generates a signal when one of the keys in the plurality of keys is pressed by a user.

18. The portable computer defined in claim **16** wherein the key antenna comprises a weak spring that flexes when the key antenna is pressed by a user.

19. The portable computer defined in claim **16** wherein the key antenna comprises a keycap and a spiral antenna resonating element located under the keycap.

20. An electronic device comprising:

keyboard circuitry;

a key antenna, wherein the key antenna is configured to generate a signal when the key antenna is pressed by a user and wherein the keyboard circuitry is configured to receive the signal when the key antenna is pressed by the user;

a radio-frequency transceiver; and

a communications path, wherein the communications path is configured to convey radio-frequency signals between the radio-frequency transceiver and the key antenna.

21. The electronic device defined in claim **20** wherein the electronic device comprises a portable computer.

22. The electronic device defined in claim **20** wherein the key antenna comprises an antenna resonating element, wherein the communications path comprises a flexible communications path that flexes when the key antenna is pressed by the user.

23. The electronic device defined in claim **22** wherein the key antenna comprises a multiband key antenna, wherein the radio-frequency transceiver comprises a multiband radio-frequency transceiver, and wherein the multiband key antenna and the multiband radio-frequency transceiver are configured to transmit and receive radio-frequency signals in at least two radio-frequency bands.

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